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# The Role of Enhanced Recovery Programmes in Elderly Patients Undergoing Thoracic Surgery

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## Abstract

**Purpose of Review** An ageing population and increasing use of imaging techniques have resulted in a greater number of elderly patients being diagnosed with localised, early stage non-small cell lung cancer (NSCLC). Several physiologic factors contribute to the challenge of thoracic surgery in elderly patients: age-related decline in pulmonary function, comorbid disease such as ischaemic heart disease, diabetes and osteoporosis; and advanced COPD in lifelong smokers. This article will discuss the potential advantages of enrolling elderly patients undergoing thoracic surgery on an enhanced recovery after surgery programme and the effect of such programmes on patient outcomes.

**Recent Findings** Several interventions implemented in the pre-, intra- and post-op periods have been shown to reduce morbidity and mortality in elderly patients undergoing pulmonary resection.

**Summary** No single intervention has the capacity to reduce morbidity and mortality in the elderly undergoing pulmonary resection; however, a series of interventions implemented as an ERAS programme has the potential to improved outcomes in this patient population.

**Keywords** Enhanced recovery after surgery programme · Lung cancer · Geriatric

## Introduction

Lung cancer is the most prevalent cancer worldwide. In 2018, there were an estimated 2.1 million lung cancer diagnoses accounting for 11.6% of the global cancer burden [1]. An ageing general population and increasing use of imaging techniques, along with advancements in imaging technology, have resulted in a greater number of elderly patients being diagnosed with localised, early stage non-small cell lung cancer (NSCLC) [2]. The median age at which lung cancer is diagnosed is 70 years, and as a result of an ageing population, there will be a future increase in the number of elderly patients who will be diagnosed with a pulmonary malignancy [3•]. Early stage non-small cell lung cancer (NSCLC) accounts for 85% of all lung cancer diagnoses and is amenable to surgical resection with curative intent [4].

Decision-making in elderly surgical patients is complicated by multiple comorbidities, polypharmacy and poor physical condition. Factors such as age, poor nutritional state and co-morbidities are known causes of delayed recovery and increased morbidity following elective surgery [5]. Several physiologic factors contribute to the challenge of thoracic surgery in elderly patients: age-related decline in lung function; comorbid disease such as ischaemic heart disease, diabetes and osteoporosis; and advanced COPD in lifelong smokers.

Frailty is associated with a decline in physiologic reserve and function across multiple physiologic systems. Sarcopenia has often been used a measurable marker of frailty in the surgical patient population. Sarcopenia is characterised by progressive and generalised loss of skeletal muscle mass and strength [6]. This is considered a separate entity to cachexia which has been defined as loss of lean tissue mass, involving a weight loss greater than 5% of body weight in 12 months or less in the presence of chronic illness or a body mass index (BMI) lower than 20 kg/m$^2$. In addition, three of the following five criteria are also met: decreased muscle strength, fatigue, anorexia, low fat-free mass index, increase of inflammation

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markers such a C-reactive protein (CRP) or interleukin 6 (IL-6) as well as anaemia or low serum albumin [7].

Physiological and anatomical changes within the lungs, as they age, must also be taken into consideration when planning operative procedures in the elderly population. Age-related osteoporosis causes loss of height of thoracic vertebrae. Additionally, stiffening of the thoracic cage secondary to calcification of ribcage and age-related kyphosis prevents the thoracic cage from expanding maximally during inspiration which places the diaphragm at a mechanical disadvantage. Lung parenchyma dilates over time resulting in dilated airspaces and a condition referred to as “senile emphysema”. The strength of respiratory muscles decreases with age, impairing an effective cough mechanism, leading to impaired airway clearance. Airway receptors in ageing lungs also undergo changes that result in altered response to drugs compared with their younger counterparts. There is a decreased sensation of dyspnoea in the older patient population accompanied by a diminished response to hypoxia and hypercapnia which places them at increased risk of ventilator failure and failure to wean during high demand states such as congestive heart failure and lower respiratory tract infection [8].

There is a significant risk that morbidity associated with thoracic surgery may lead to deterioration in global health and function post-operatively and subsequently impaired quality of life that continues after the patient returns home. Recently, a large body of work has been conducted on investigating frailty within the elderly population and how this phenomenon can be assessed within this patient population [9]. Frailty is defined as a clinically recognisable state of increased vulnerability to physiologic stressors resulting from ageing.

Despite advances in surgical procedures and perioperative care, patients undergoing thoracic surgery still have a 25% risk of post-operative pulmonary complications and a mortality risk of up to 7.5%. Risk factors for complications in thoracic surgery include advanced age, poor preoperative pulmonary function and cardiovascular comorbidity [10].

Extensive research has been carried out into enhanced recovery programmes in specialties such as colorectal, orthopaedic surgery and gynaecology. Enhanced recovery programmes are defined as a series of evidence-based practices with the intent of optimising the patient before surgery, minimising the physical and psychological stress associated with the procedure and promoting the restoration of function [11]. These programmes have been shown to reduce the rate of post-operative complications and to shorten length of hospital stay significantly. Additionally, they have financial implications by reducing healthcare costs by producing productivity savings [11].

However, comparatively, little work has been done to develop enhanced recovery programmes for patients undergoing thoracic surgery. The most common complications reported after thoracic surgery include acute lung injury, persistent air leak and chronic pain [12]. It has been postulated that not all elderly patients will be capable of complying with an enhanced recovery programme. However, elderly patients have higher rates of comorbidity, frailty and greater social care needs. Therefore, it could be argued that these patients are in greater need of interventions such as enhanced recovery programmes to optimise speed of recovery and to avoid post-operative complications and the associated loss of function and quality of life [13].

This article will discuss the potential advantages of enrolling elderly patients undergoing thoracic surgery on an enhanced recovery after surgery programme and the effect of such programmes on patient outcomes.

## Preoperative Workup

Patients enrolled on an enhanced recovery programme are assessed in a pre-assessment clinic several weeks prior to their scheduled date for surgery. The risk of disease upstaging also poses a challenge in delivering an ERAS programme in as short as time possible. A large proportion of the patients being initiated on the thoracic surgery enhanced recovery programme will be due to undergo lung resection for treatment of malignancy. As such, smoking history will be frequently observed, in addition to a background medical history of COPD, ischaemic heart disease, peripheral vascular disease and renal function impairment [12, 14]. Smoking cessation advice is central to the pre-assessment protocol in this patient cohort. Interventions such as nicotine replacement therapy have been used in the preoperative period; however, there is limited evidence for its efficacy [15]. There is no evidence of a paradoxical increase in pulmonary complications among patients who stop smoking within 2 months of thoracotomy. NICE guidelines recommend that smoking cessation advice should be given to patients as soon as a diagnosis of lung cancer is suspected [11]. Medical management of comorbidities must also be optimised in the weeks prior to thoracic surgery to prevent complications such as infective exacerbations of COPD or cardiac ischaemia in the post-operative period.

Baseline measurements of patient function may help identify those who are at risk of post-operative complications. Assessment of exercise capacity such as shuttle walk test and stair climbing, along with formal investigations such as pulmonary function tests, is useful [11]. Low post-operative predictive values of FEV1 (ppoFEV1) and diffusion capacity for carbon monoxide (DLCO) (ppoDLCO) are used to exclude patients from surgery as these variables are reported to be independent predictors of post-operative morbidity and mortality in thoracic surgery [16•]. As recommended in the ERS/ESTS clinical practice guidelines, patients with a ppoFEV1 and ppoDLCO < 30% are considered too high risk to undergo lung resection. In patients considered to be suitable for anatomical resection of lung tumour, almost 37% are considered inoperable secondary to severe pulmonary impairment secondary to conditions such as COPD [16•]. This is commonly seen in elderly patients who often have a lifetime smoking history. Pulmonary rehabilitation has become a cornerstone of COPD management. Rehabilitation programmes including physical exercise and education have demonstrated benefit from even short-term programmes of 2-week duration. Due to the high rate of COPD in patients undergoing lung resection for malignancy, it is expected that similar programmes would also show benefit in this patient population. Pulmonary rehabilitation can improve exercise capacity, dyspnoea, activities of daily living, muscle strength, self-efficacy and quality of life [17].

Endurance training has shown an improvement in aerobic performance as a result of blood volume expansion, higher cardiac output and enhanced muscle oxygen extraction. It also results in a concomitant increase in inspiratory muscle strength. However, such programmes require 6–12 weeks to show an improvement in patient function. This is longer than the recommended time between diagnosis of malignancy and lung resection. As such, exercise programmes of shorter duration are required. High-intensity interval training (HIIT) has been suggested as an alternative, with programmes shown to improve patient function in 2–6 weeks [16•]. Preoperative pulmonary rehabilitation has been shown to decrease post-operative complication rates in patients undergoing thoracic surgery. Gao et al. published a study in which preoperative respiratory training included training for abdominal breath, breath training device (volumetric exerciser) and lower extremity endurance training. This was done for 30–40 min a day for 3–7 days. Post-operative complications were less frequent in the study group (16.9%) than the control group (83.3%). The control group had a longer post-operative length of hospital stay. There was no difference in the cost of hospital stay between the groups, including the cost of pulmonary rehabilitation [18]. Exercise programmes to improve patient functional status are also beneficial to elderly, frail patients. In older patients, physical fitness and activity are strongly associated with post-operative outcomes such as mortality, length of hospital stay and return to preoperative functional status. There is a growing body of evidence to suggest that inspiratory muscle training decreases the incidence of post-operative pulmonary complications in elderly patients after thoracic surgery. Preoperative aerobic exercise training is also associated with improved physical fitness of patients before and improved functional recovery after thoracic surgery [19].

Optimisation of patient nutrition is a key component of enhanced recovery after surgery programmes. Suboptimal nutrition is associated with impaired wound healing, immune dysfunction, respiratory muscle fatigue and tissue wasting post-operatively [11]. The European Society for Nutrition and Metabolism Guidelines state that patients at increased risk of malnutrition are identified by the following criteria: weight loss of 10–15% within 6 months, BMI < 18.5, Subjective Global Assessment C and serum albumin < 30 [20]. In total, it is estimated that 28% of patients with lung cancer, amenable to resection, are said to be at increased risk of malnutrition [21]. Disease-related malnutrition has been defined as a condition resulting from the activation of the systemic inflammatory response by an underlying disease. The inflammatory response results in anorexia and tissue degradation which leads to significant weight loss, alterations in body composition and decreased functional capacity.

Cancer cachexia, specifically, is characterised by involuntary sustained weight loss and skeletal muscle mass. This may or may not be associated with a loss of fat mass. It is not reversable by nutritional support and results in severe functional decline [21]. Elderly patients are also at increased risk of malnutrition, and this also contributes to the aetiology of sarcopenia and frailty. Nutritional intake is often decreased in elderly patients, frequently due to anorexia of ageing. Reduced dietary intake in combination with the effects of catabolic disease leads to malnutrition. Malnutrition puts elderly patients at an increased risk of negative outcomes such as infections and pressure ulcers, increased length of hospital stay, increased duration of convalescence after acute illness as well as increased mortality [22]. Therefore, elderly patients with lung cancer are at significant risk of malnutrition and its associated poor surgical outcomes. There is a paucity of evidence regarding the correction of preoperative malnutrition in lung cancer patients. The effect of micronutrient supplementation in NSCLC patients was investigated in a small prospective study. The combination of α-ketogluric acid and 5-hydroxymethylfurfural improved exercise capacity, reduced oxidative stress and resulted in a significant reduction in ICU and hospital stay [23]. As part of preoperative nutrition assessment, alcohol intake should also be recorded so that treatment to prevent alcohol withdrawal can be prescribed and alcohol cessation can be achieved prior to surgery [12]. A study by Al-Refaie et al. demonstrated the importance of measuring and recognising preoperative hypoalbuminaemia, as a marker of malnutrition, in elderly surgical patients, particularly in those who are undergoing major oncologic surgery.

Preoperative detection and treatment of anaemia is useful in the reduction of post-operative morbidity in elderly patients. Perioperative blood transfusion is commonly used to increase haemoglobin concentration but is also associated with the increased risk of acute transfusion reactions, immunosuppression, post-operative infection and longer hospital stay. Elderly patients are also at increased risk of comorbidities such as congestive cardiac failure, which places them at risk of pulmonary oedema requiring diuretics after blood transfusion [24] . Perioperative iron supplementation and

EPO are alternative strategies which may decrease the need for blood transfusion. Studies of iron supplementation before treatment with chemotherapy and radiotherapy in the setting of lung therapy have been conducted; however, none as yet have assessed their effectiveness prior to lung resection [11, 25]. Strategies to reduce blood loss intraoperatively may also be deployed such as the use of cell saver device.

Patients undergoing thoracic surgery are considered to be at high risk of venous thromboembolism (VTE) [11]. NICE guidelines recommend that this cohort of patients receive mechanical VTE prophylaxis in the form of anti-embolism stockings, intermittent pneumatic compression devices or foot impulse devices from time of admission (NICE). For those patients who are at a low risk of bleeding, pharmacological prophylaxis should be considered. Impaired renal function is a potential comorbidity in the elderly population, and so low molecular weight heparin should be prescribed with caution. Additionally, pharmacological VTE prophylaxis should be prescribed with caution in patients who are due to receive regional anaesthetic blocks as analgesia post-operatively [11].

Preoperative fasting is often prescribed by the traditional protocol of "fast from midnight", allowing for at least 6 hours of nil by mouth prior to surgery. However, it has now been shown that carbohydrate drinks may reduce post-operative endocrine responses. As such, it is now common in enhanced recovery programmes to allow patients to drink such carbohydrate drinks, which are clear fluids, up until 2 hours before surgery [10]. Long-acting benzodiazepines are also not recommended in the preoperative period for thoracic surgery. This has been shown to delay early extubation, early ambulation and early oral feeding as part of the enhanced recovery programme [26]. Sedative effects of benzodiazepines are more severe in elderly patients and could result in this patient cohort being unable to benefit from an enhanced recovery programme.

The Thoracic Surgery Scoring System (ThoraScore) is the most commonly utilised scoring system for predicting postoperative morbidity and mortality in patients undergoing thoracic surgery. The variables within the score associated with increased risk of mortality are summarised in Table 1. These comorbidities and their management need to be optimised in the preoperative period in order to decrease the risk of postoperative morbidity and mortality in thoracic surgery [11, 27].

**Table 1** ThoraScore variables associated with increased risk of death after thoracic surgery

| |
|---|
| • Increasing age |
| • Male sex |
| • Increasing ASA grade |
| • Nature of surgery, e.g., pneumonectomy vs lobectomy |
| • Malignant pathology |
| • Major comorbidity—elderly population, smoking addiction, history of cancer, COPD, arterial hypertension, cardiac disease, diabetes, peripheral vascular disease, obesity, alcoholism |
| • Functional status—FEV1 or TLCO of < 40%, VO2 max < 15 ml/kg/min |

## Intraoperative Considerations

There are currently no guidelines for antibiotic prophylaxis in thoracic surgery [11, 28]. This is complicated by the likelihood that elderly patients who are undergoing thoracic surgery will have had multiple respiratory tract infections over the course of their lifetime, and as a result, their respiratory tracts are likely to be colonised by multiple drug-resistant bacteria [29]. Choice of prophylactic antibiotic should therefore comply with local guidelines to ensure adequate coverage in the perioperative period. As with all surgical antibiotic prophylaxis, drugs should be administered within 60 min of "knife to skin" in accordance with the WHO Safer Surgery Checklist [30].

Choice of anaesthetic agent is an important consideration in thoracic surgery. In thoracic anaesthesia, inhibition of hypoxic pulmonary vasoconstriction may result in intraoperative hypoxaemia. Inhibition of hypoxic pulmonary vasoconstriction by inhalational anaesthetic agents is well studied. Ether, halothane and nitrous oxide inhibit hypoxic pulmonary vasoconstriction in a dose-dependent manner. Isoflurane, desflurane and sevoflurane are reasonably neutral towards hypoxic pulmonary vasoconstriction. IV anaesthesia with agents such as propofol was proposed as a method of avoiding inhibition of hypoxic pulmonary vasoconstriction; however, it is rarely used in clinical practice as the improvement in oxygenation is minimal.

Other factors such as hypothermia, haemodilution and increased left atrial pressure also inhibit hypoxic pulmonary vasoconstriction [31]. These physiological parameters are critical considerations in one lung ventilation (OLV). Volatile anaesthetic agents are also associated with less awareness in thoracic surgery compared with intravenous anaesthetic agents. Nitrous oxide is avoided in thoracic anaesthesia because it diffuses into and enlarges airspaces and is especially avoided in patients with a history of emphysema. It has been shown that volatile anaesthetic agents, but not propofol, can reduce the expression of inflammatory mediators such as tumour necrosis factor, interleukin 8 and interleukin one beta into bronchoalveolar lavage fluid. These findings were correlated with significantly more inflammatory and infective complications in patients anaesthetised with propofol compared with those anaesthetised with sevoflurane. There was no associated increase in mortality; however, there were more surgical interventions, prolonged hospital stay and antibiotic requirements in the propofol group [32]. The effect of anaesthetic agents on cognitive function is a significant consideration in elderly patients undergoing thoracic surgery. Post-operative cognitive dysfunction (POCD) is a common complication after surgery and is common in elderly patients and patients with pre-existing neurocognitive disorders [33]. POCD has been defined as any significant reduction in cognitive performance from baseline following an operative procedure. It is diagnosed as defects in multiple core neurocognitive domains, including executive function, attention, verbal memory, psychomotor speed and visuospatial abstraction [33]. Volatile agents have been associated with cognitive dysfunction. Sevoflurane induces apoptosis and caspase activation in brain cells. It also enhances beta-site amyloid precursor protein cleaving enzyme and Aβ concentrations, which induce further rounds of apoptosis and cell death [32]. Data from both animal and human studies suggests that neuroinflammation from surgery or anaesthesia is a contributor to POCD. Advanced age is strongly associated with POCD; incidence is reported at 1–54% 1 week after surgery in patients aged over 65 years; 10–17% 3 months after surgery and 3% 12 months post-operatively [33].

One lung ventilation is a unique consideration in thoracic surgery that can have major consequences on patient outcomes. Efficiency of gas exchange is dependent on matching of perfusion to ventilation. Homeostatic control is exerted through vasoconstriction of poorly ventilated areas of the lung, resulting in diversion of blood flow to better ventilated areas which leads to better ventilation/perfusion (V/Q matching), which is challenged in OLV. Several mechanisms aid in reducing blood flow to the non-ventilated lung: surgical manipulation, lateral position, gravity and hypoxic vasoconstriction increases vascular resistance. Acute lung injury (ALI) after pulmonary resection occurs in 2.45% of patients, with a peak incidence of 7.9% in patients undergoing pneumonectomy. This is a spectrum of injury ranging from mild ALI to acute respiratory distress syndrome (ARDS). Increased duration of OLV is a risk factor for the development of ALI. It is prudent to ensure that all thoracic surgeries are performed in as short a procedure as possible to minimise morbidity, particularly in elderly patients who are more susceptible to such complications. Oxygen toxicity is also known to occur in OLV as a result of ischaemia reperfusion injury and oxidative stress. Collapse of the operative lung and surgical manipulation causes organ ischaemia and subsequent production of radical oxygen species when the lung is reventilated and reperfused. Prolonged OLV and the presence of a tumour result in increased levels of markers of oxidative stress. OLV of a duration longer than 120 min is associated with increased rates of respiratory failure and mortality. Mechanical ventilation may be detrimental to critically ill patients due to ventilator-induced lung injury. High tidal volumes can cause damage to the ventilated lung, which is known as “volutrauma”. Protective lung ventilation, consisting of small tidal volumes (approx. 6 ml/kg) and high positive end-expiratory pressure (PEEP) can reduce the incidence of ALI. High tidal volumes can result in excessive end-inspiratory stretch during OLV, similar to ARDS [32]. OLV also induces cytokine release and activation of the pulmonary inflammatory response [11]. This has been associated with post-operative cognitive dysfunction in patients undergoing thoracic surgery, which is of particular relevance in elderly surgical candidates [34]. Prolonged OLV results in oxidative stress and free radical generation. Hypoxaemia which occurs during OLV also triggers release of proinflammatory cytokines which are known to affect neurotransmitter systems and, therefore, neurocognitive performance. A study by Sungur et al. demonstrated that prolonged OLV resulted in increased duration of hypoxaemic episodes which in turn was associated with deterioration in cognitive testing performance in those patients who experienced intraoperative desaturations [35]. It has been postulated that as inflammation is involved in cerebral dysfunction, anti-inflammatory strategies in the perioperative setting seem to be potential neuroprotective targets concerning especially high-risk patients undergoing thoracic surgery under OLV [36].

The use of prophylactic high-flow nasal oxygen therapy has recently been tested in an attempt to decrease complications after thoracic surgery. Ansari et al. has reported that use of high-flow nasal oxygen therapy resulted in a shorter length of hospital stay and increased patient satisfaction after lung resection. However, there was no improvement in 6-min walk test or overall recovery [37].

Choice of surgical technique is an important consideration in enhanced recovery programmes. Video-assisted thoracoscopic surgery (VATS) has been shown to improve post-operative pain in patients undergoing thoracic surgery; however, there is little evidence currently to suggest that VATS reduces morbidity and mortality compared with thoracotomy approach [10]. It is also thought to decrease the stress response that is often seen with thoracotomy. However, VATS can also be associated with longer OLV times, particularly with inexperienced surgeons, which are associated with the development of acute lung injury.

This should be taken into consideration in the elderly patient population who are more susceptible to ALI than younger patients with fewer pulmonary comorbidities. VATS tends to be the preferred surgical approach in the case of ERAS programmes; however, similar patient outcomes have been shown with thoracotomy [12]. VATS may convey an economic advantage over thoracotomy, however. A study by Preventza et al. demonstrated that overall hospital charges were nearly half that of the charges for patients undergoing open thoracotomy as part of an enhanced recovery programme [38]. Muscle-sparing incisions can also be considered a method of pain reduction post-operatively where VATS may not be suitable. Anterolateral thoracic incisions are less painful than the tradition posterolateral approach [26]. As such, use of VATS and alternative incisions to the posterolateral approach may result in less impairment of functional vital capacity and improved exercise tolerance in the post-operative period, improving patient outcomes [11]. Lobectomies undertaken by robotic-assisted approaches have a longer operative time, but quality outcome measures, including complications, hospital stay, 30-day mortality and nodal upstaging, suggest that robotic lobectomy and VATS are equivalent [39].

Chest drains are a significant source of morbidity post thoracic surgery, primarily as a result of pain. Minimising use of surgical drains to one is central to ERAS in thoracic surgery, particularly in elderly patients whose mobility is often hampered by drains post-operatively [26]. A higher threshold for chest drain removal such as < 450 ml non-chylous, non-haemorrhagic output in 24 h would facilitate short length of chest drain in situ in the majority of patients post-lung resection [12]. Removal of the chest drain is often delayed as a result of persistent air leak. There are a range of surgical sealants available that are hypothesised to decrease the rate of air leak; however, these are high-cost interventions, and there is little evidence to show that they are an effective intervention [11]. Cerfolio et al. reported on a unique ERAS programme in thoracic surgery for patients with persistent air leak. In this group, a Heimlich valve was fitted for 24 h, and a chest x-ray was performed. Asymptomatic patients were discharged home with the Heimlich valve attached to a leg bag [40]. These strategies are useful for decreasing length of hospital stay for patients undergoing pulmonary resection. The type of chest drain used is also relevant. The use of the traditional underwater seal drainage system allows for greater variability among practices. They also do not offer accurate data with regard to air leak. All digital drainage systems are portable, allowing for post-operative mobilisation. They also have alarms for various situations, including but not limited to tube occlusion, disconnection and suction failure. It is also a closed system, so the fluid has no contact with the outside environment and provides improved biosafety to the patient and healthcare staff. Digital chest drains also eliminate interobserver variability with objective measurement of air leaks recorded in the system and displayed on a screen [41].

## Post-Operative Course

Immediate tracheal extubation after thoracic surgery is central to ERAS programmes. Prolonged mechanical ventilation is associated with significant complications of acute lung injury, pulmonary infection, bronchial stump disruption, bronchopleural fistula and persistent air leak [11]. Early extubation also allows for immediate initiation of post-operative rehabilitation with mobilisation or reintroduction of oral hydration and nutrition.

Several risk factors for prolonged intubation after thoracic surgery have been identified: intraoperative blood transfusion, raised preoperative serum creatinine, more extensive lung resection and poor preoperative pulmonary function. A study by Das-Neves-Pereira described an ERAS programme where immediately following extubation in the operating room, patients were placed in a seated position and started on physiotherapy exercises. During transport to the ICU, patients performed physical exercises including movement of the upper extremities alongside deep inspiration with a 2-s inspiratory apnoea, followed by movement of the lower extremities accompanied by deep expiration [26]. This ERAS programme also early mobilisation as a method of decreasing complications. Upon reaching the ICU, patients were immediately encouraged to keep moving their extremities, breathe deeply, cough and remain in a seated position for up to a 50-min period. This programme found that avoidance of long-duration benzodiazepines, performing immediate extubation, thoracic regional patient-controlled analgesia, early ambulation and oral feeding all seem to be related to a lower frequency of complications and shorter hospital stay. However, multivariate analysis identified only early ambulation as a predictive variable of post-operative complication [26].

Patients can be safely mobilised 4 h post thoracic surgery. Prolonged bed rest in the post-operative period is associated with impaired pulmonary function, reduced muscle mass and increased risk of VTE, all of which are exacerbated in the elderly patient. Involvement of a chest physiotherapist in the early post-operative period has been shown to reduce the risk of pulmonary complications, length of hospital stay and cost of care after lung resection [11]. Li et al. studied rehabilitation in elderly patients undergoing lung resection. Rehabilitation in the immediate post-operative period, including early mobilisation, was carried out with the intention of decreasing post-operative pulmonary complications (PPCs), preventing deconditioning and facilitating early and safe discharge. A PPC is defined as any pulmonary sequelae occurring during the post-operative period and resulting in significant dysfunction, adversely affecting the clinical course. Issues encountered included pneumonia, atelectasis, acute respiratory failure, need for reintubation, pulmonary oedema, bronchospasm, pneumothorax and prolonged air leak. Age over 75 years was cited as an independent risk factor for PPC [42•].

In addition to early removal of endotracheal tubes, urinary catheters should either be avoided altogether or removed at the early opportunity in thoracic surgery ERAS programmes. Urinary catheters are associated with decreased mobilisation and are a falls risk in elderly patients in the perioperative period.

Avoidance of fluid overload is paramount in preventing complications post thoracic surgery [12]. Liberal fluid administration after thoracic surgery has been linked to increased rates of acute lung injury. However, despite this, no goal-directed IV fluid therapy protocol has been validated for thoracic surgery. Anaesthetists often aim to achieve a

**Table 2** Potential elements of an enhanced recovery after surgery programme for elderly patients undergoing thoracic surgery

| Preoperative | Intraoperative | Post-operative |
|---|---|---|
| Pre-assessment clinic, optimisation of management of comorbidities, smoking cessation advice, pulmonary function testing, pulmonary prehabilitation programmes, exercise prehabilitation programmes, assessment and optimisation of nutritional status, detection and treatment of anaemia, VTE prophylaxis, shortened preoperative fasting, preoperative carbohydrate load, avoidance of long-acting benzodiazepines, ThoraScore | Antibiotic prophylaxis, choice of anaesthetic agent, optimisation of OLV, prophylactic high-flow nasal oxygen therapy, VATS vs muscle sparing thoracotomy, digital chest drains | Immediate tracheal extubation, avoidance of urethral catheterisation, avoidance of fluid overload, regional analgesia, avoidance of opiate analgesia, hospital discharge destination |

perioperative negative fluid balance to avoid complications [26]. Elderly patients are a population that are at increased risk of fluid overload and the subsequent risks of this event.

It is widely accepted that thoracic surgery incisions are associated with significant post-operative pain and require effective analgesia. Acute pain after thoracotomy prevents early mobilisation, causes distress and is associated with increased incidence of complications including atelectasis, pneumonia, atrial fibrillation and myocardial ischaemia [11]. Elderly patients are at significant risk of adverse drug reactions often as a result of impaired renal function and chronic kidney disease which is more prevalent in this patient population. Due to renal clearance of many analgesic medications, it is critical to adjust doses accordingly. Elderly patients are also more sensitive to the psychoactive effects of medications such as opiates and benzodiazepines. Polypharmacy in the elderly patients has also been associated with an increased risk of cognitive impairment, morbidity and mortality, in addition to decreased medication compliance in some cases [43]. All of these factors increased the complexity of pain management in the elderly thoracic surgery patient. In thoracic surgery, multimodal analgesia with NSAIDs, paracetamol, opiates and a surgically inserted paravertebral catheter allows good pain relief with minimal respiratory depression in the general population [12]. However, NSAIDs and opiates should be prescribed with caution in the elderly. Epidural analgesia had been central to pain management in thoracic surgery. However, it is associated with adverse effects such as urinary retention, hypotension and muscular weakness which decrease its attractiveness in an ERAS programme, particularly in elderly patients.

The increased prevalence of patients on dual antiplatelet therapy, chronic kidney disease and oral anticoagulation increases the likelihood of epidural bleeding. It may be prudent to reserve use of epidural analgesia for high-risk patients not expected to follow an ERAS programme, e.g., those undergoing chest wall reconstruction or pneumonectomy [11]. Paravertebral blockade provides a unilateral block of sympathetic and somatic nerves and does not have the potential associated complications of epidural analgesia, making it a feasible intervention in thoracic surgery [12]. The use of gabapentin in the preoperative period in addition to the post-operative period has been shown to improve pain scores when compared with PCA morphine alone. Therefore, analgesia should be a part of prehabilitation in thoracic surgery to allow for effective post-operative pain relief, early mobilisation and effective physiotherapy, diminishing rates of pulmonary complications and, therefore, reduction of hospital stay. Regional anaesthesia is also regarded as the best available technique for attenuating the endocrine metabolic response and also reducing the production of pro-inflammatory cytokines and their effect on systemic inflammation and multi-organ dysfunction, including cognitive dysfunction, as previously discussed [10].

**Table 3** Single-centre experience of introducing an enhanced recovery after surgery programme in patients aged 65 years and older compared with standard care

| | ERAS | Standard care | *p* value |
|---|---|---|---|
| Age | 71.31 ± 5.2 years | 72.54 ± 5.14 | 0.35 |
| Gender | | | 0.95 |
| Male | 19 | 15 | |
| Female | 17 | 13 | |
| Length of chest drain in situ | 3.81 ± 3.9 | 7.36 ± 5.5 | 0.005 |
| Length of post-op hospital stay | 6.22 ± 3.25 | 9.37 ± 5.32 | 0.004 |

Prophylactic use of anti-emetics has also been considered to prevent nausea and vomiting associated with general anaesthetic agents and analgesia which may result in delayed ambulation, aspiration and further pulmonary complications [16, 26].

A high proportion of elderly patients may require discharge to a nursing home or rehabilitation facility. These requirements should be flagged in the preoperative assessment so that arrangement can be made, allowing for a timely discharge from the acute hospital setting post thoracic surgery. A systematic review of ERAS programmes in elderly patients showed that 10% of patients over the age of 80 years required discharge to a nursing home facility or rehabilitation centre. Liaison with geriatricians would be useful in minimising avoidable delay in hospital discharge by optimising management of geriatric syndromes and pre-emptively addressing the needs of elderly patients in the post-operative period [13]. This is common in many orthopaedic services with the creation of "orthogeriatrics". It has been shown that there is improved outcomes in elderly patients who were assessed and treated by orthogeriatricians after hip fracture [44].

The pre-, intra- and post-operative components of an enhanced recovery after surgery programme for elderly people are summarised in Table 2.

## Our Experience

In 2016, we introduced an ERAS programme for patients undergoing lung cancer resection at our institution, a tertiary referral centre for thoracic surgery on the west coast of Ireland. This programme composes of preoperative physiotherapy, preoperative nutrition, preoperative oral analgesia, intraoperative local infiltration analgesia and paravertebral blockade, avoidance of urethral catheterisation, digital thoracic drains and early mobilisation after surgery. All patients undergoing lung cancer resection are entered onto this programme regardless of age. The outcomes of elderly patients treated with the ERAS programme were compared with those of elderly patients treated with standard care prior to the introduction of the programme. All patients aged 65 years or older were considered elderly. Overall, the outcomes of 64 patients were examined, 36 who underwent the ERAS programme and 28 who were treated with standard care. There was no statistically significant difference in the age of patients between the two groups (ERAS 71.3 years ± 5.2 years; standard care 72.5 years ± 5.1 years; $p = 0.35$, $t$ test) or in the gender between the two group (ERAS male 52.8%, female 47.2%; standard care male 53.6%, female 46.4%; $p = 0.95$, Pearson Chi square) (Table 3). Length of chest drain in situ and length of hospital stay post-operatively were analysed in both patient groups. Chest drains remained in situ for a mean of 3.81 ± 3.9 days in the ERAS group compared with 7.36 ± 5.5 days in the standard care group ($p = 0.005$). Patients treated with the ERAS protocol also had a shorter length of hospital stay (6.2 ± 3.3 days) than those treated with standard care (9.4 days ± 5.3 days) ($p = 0.004$).

## Conclusion

Enhanced recovery programmes are a recent occurrence in the field of thoracic surgery. However, they have demonstrated their efficacy and importance in other surgical fields. Many of the principles of ERAS programmes from other specialties are transferable to thoracic surgery; however, elements must be tailored specifically to this patient population. While it has been argued that this patient population may not be capable of following an ERAS programme, they are likely to group that to most in need of such an intervention in order to reduce morbidity and mortality. We recommend that all thoracic surgical services provide an ERAS programme, particularly in the case of elderly patients.

## Compliance with Ethical Standards

**Conflict of Interest** None of the authors of this manuscript have conflicts of interest to declare.

**Human and Animal Rights and Informed Consent** This article does not contain any studies with human or animal subjects performed by any of the authors.

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Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance


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